Modeling Primary and Secondary Emotions for a Believable Communication Agent

Christian Becker, Ipke Wachsmuth

Faculty of Technology
University of Bielefeld
33594 Bielefeld
Germany
{cbecker,ipke}@techfak.uni-bielefeld.de

Abstract. The integration of emotion and cognition in cognitive architectures for embodied agents is a problem of increasing importance. In this paper, we describe how two separate modules for these tasks, as we employ them in our virtual human Max, can give rise to secondary emotions such as frustration and relief. The BDI-based cognitive module is responsible for appraisal as well as reappraisal of elicited emotions that our conversational agent Max becomes aware of. The emotion dynamics simulation system is driven by the valence information of every emotion and assures a general consistency of the simulated emotions over time by dynamically providing an awareness likelihood for every emotion.

1 Introduction and Motivation

When trying to build socially intelligent agents, the integration of simulated emotions into an agent's cognitive architecture seems to be unavoidable. In our work we follow the ideas of cognitive modeling with a cognitive architecture based on the BDI-theory and an emotion dynamics simulation system based on dimensional emotion theories. We further follow the ideas of [5] by distinguishing "primary" and "secondary" emotions. "Primary" emotions are elicited as an immediate response to a stimulus, whereas "secondary" emotions are the product of cognitive processing. Up to now our set of simulated emotions has been limited to undirected, "primary" emotions such as fear, sadness, anger and happiness. After we validated a desirable effect of these emotions empirically [4], we now want to let our agent control its own emotions to prepare him for social scenarios, where the application of coping strategies is necessary. In these situations the general limitation on "primary" emotions must also be overcome by further combining cognition and emotion to simulate "secondary" emotions such as frustration and relief as well.

In the next section, we will start with an overview of related work along the lines of two major emotion research trends in psychology. In Section 3, we introduce our virtual agent's modular architecture and describe our approach to simulate primary and secondary emotions as a combination of cognitive appraisal and an underlying emotion dynamics. We conclude this paper by discussing some advantages and possible drawbacks of our architecture.

2 Related Work

According to [1] at least two main viewpoints can be distinguished in modeling emotions: cognitive theories of emotions and dimensional theories of emotions.

The well-known OCC-approach [11] to emotion simulation relies on rational reasoning about the eliciting factors of emotions. Appraisal is the basis of every computational emotion theory, but in the OCC model it is indistinguishably intertwined with the cognitive processing of an agent. Despite its comprehensiveness and explanatory power, this model was frequently criticized, e.g., for not taking into account the mutual interaction of emotion categories. Ortony himself [10], however, has proposed later that it might be sufficient to simulate only ten emotion categories and that it may even be adequate to start with an agent that can only differentiate positive from negative, letting it evolve richer emotional experience by means of machine learning techniques.

Initially Wundt [12] has claimed that any emotion can be characterized as a continuous progression in a three-dimensional space of connotative meaning and several researchers (e.g. [7]) have provided statistical evidence for this assumption. These dimensions are commonly labeled *Pleasure/Valence (P)*, representing the overall valence information, *Arousal (A)*, accounting for the degree of activeness of an emotion, and *Dominance/Control (D)*, describing the experienced "control" over the situational context (PAD-space, in short).

We combine these approaches as they can complement each other in a reasonable and beneficial way.

3 Simulating Primary and Secondary Emotions

Our virtual human Max is a testbed for studying and modeling human-like communicative behavior in natural face-to-face interactions [6]. Max architecture consists of a cognition module and an emotion module (see Figure 1).

The cognitive module builds on the belief-desire-intention model (BDI, in short) of rational behavior. It can be divided further into a reasoning layer, in which the agent's conscious deliberation takes place, and a reactive layer, which is mainly responsible for the agent's unconscious generation of reflex behaviors.

Two major assumptions, as supported by psychology literature (e.g. see [9]), are underlying our realization of a concurrent emotion dynamics simulation module. First, emotions have a fortifying or alleviating effect on the mood of an individual and an emotion is a short-lived phenomenon. A mood, in contrast, is a longer lasting, valenced state. The predisposition to experience emotions changes together with the mood, e.g. humans in a positive mood are more susceptible to positive than negative emotions, and vice versa [8]. This "emotion dynamics" is realized in the first component of the emotion module labeled *dynamics/mood* in Figure 1. Second, every primary as well as secondary emotion can be positioned in the PAD emotion space introduced above with respect to its inherent degree of *Pleasure*, *Arousal* and *Dominance*. This assumption underlies the second component of the emotion module labeled *PAD-space* in Figure 1.

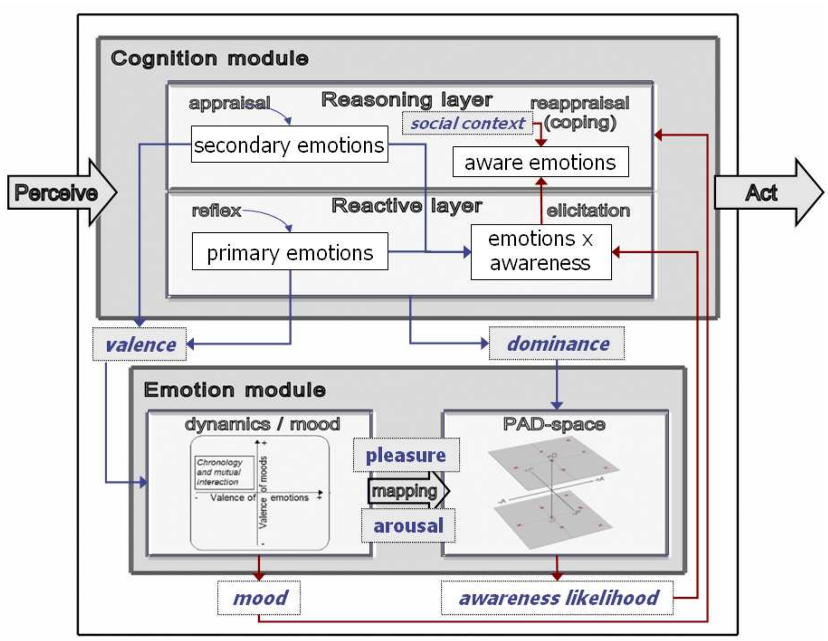

Fig. 1. The mutual interaction of cognition and emotion. A stimulus is appraised leading to the elicitation of primary and secondary emotions. Emotional valence and dominance values drive the emotion module to calculate an emotion awareness likelihood, which is used to filter the elicited emotions. Finally, the aware emotions are reappraised in the social context.

The emotion module [2] processes valenced impulses together with the actual degree of dominance as input signals. The valence information is driving the *dynamics/mood* part by changing the emotional valence on the *valence of emotions* axis. This leads to an increase or decrease of the agent's *valence of moods* indirectly, which is sent back to the cognition module as a general indicator of the agent's well being. Pleasure and arousal are derived from these values mathematically and combined with the actual value of dominance. As every emotion is represented by its corresponding PAD-triple in *PAD-space*, a distance metric is used to calculate an *awareness likelihood* for every emotion. For example, the secondary emotion "frustration" can be associated with negative pleasure and high dominance whereas "relief" can be characterized by positive pleasure and medium arousal. The primary emotions "sadness" and "anger", however, are co-located in the same region as frustration so that in case of negative pleasure and high dominance either anger, sadness or frustration might be elicited as encoded in the *awareness likelihood*. This *awareness likelihood* is sent back to the *elicitation* subcomponent of the cognition module and applied as a filter on the *primary* and *secondary* emotions that may have resulted from the initial appraisal processes. The actual set of emotions that the agent becomes aware of (the so-called *aware emotions*) are finally reappraised taking the *social context* into account. These *aware emotions* can influence the reasoning process on a sub-symbolic level as explained in [3].

4 Discussion and Conclusion

We presented a cognitive architecture for emotion simulation that combines cognitive and dimensional emotion theories. The BDI-based reasoning power of the cognitive module is used to generate secondary emotions by appraisal and reappraisal, while on a reactive layer primary emotions are concurrently realized. A possible drawback is that our architecture might suppress plausible mixtures of emotions such as fear and joy occuring at the same time, e.g., when taking a joy-ride in a roller coaster. The advantage of the proposed combination of separate modules for cognition and emotion lies in the fact that simultaneous elicitation of conflicting secondary emotions such as frustration and relief can be successfully avoided.

References

1. C. Bartneck. How convincing is Mr. Data's smile?: Affective expressions of machines. In *User Modeling and User-Adapted Interaction*, volume 11, pages 279–295, 2001.
2. C. Becker, S. Kopp, and I. Wachsmuth. Simulating the emotion dynamics of a multimodal conversational agent. In *Workshop on Affective Dialogue Systems*, pages 154–165, 2004.
3. C. Becker, N. Lessmann, S. Kopp, and I. Wachsmuth. Connecting feelings and thoughts - modeling the interaction of emotion and cognition in embodied agents. In *Proceedings of the Seventh International Conference on Cognitive Modeling (ICCM-06)*, pages 32–37, Trieste, 2006. Edizioni Goliardiche.
4. C. Becker, H. Prendinger, M. Ishizuka, and I. Wachsmuth. Evaluating affective feedback of the 3d agent Max in a competitive cards game. In *Affective Computing and Intelligent Interaction*, pages 466–473, 2005.
5. A. R. Damasio. *Descartes' Error, Emotion Reason and the Human Brain.* Grosset/Putnam, 1994.
6. S. Kopp, B. Jung, N. Lessmann, and I. Wachsmuth. Max - A Multimodal Assistant in Virtual Reality Construction. *KI-Künstliche Intelligenz*, 4/03:11–17, 2003.
7. A. Mehrabian. Framework for a comprehensive description and measurement of emotional states. *Genetic, Social, and General Psychology Monographs*, 121:339–361, 1995.
8. R. Neumann, B. Seibt, and F. Strack. The influence of mood on the intensity of emotional responses: Disentangling feeling and knowing. *Cognition & Emotion*, 15:725–747, 2001.
9. K. Oatley and P. N. Johnson-Laird. Towards a cognitive theory of emotions. *Cognition & Emotion*, 1:29–50, 1987.
10. A. Ortony. *Emotions in Humans and Artifacts*, chapter On making believable emotional agents believable, pages 189–212. MIT Press, 2003.
11. A. Ortony, G. L. Clore, and A. Collins. *The Cognitive Structure of Emotions.* Cambridge University Press, Cambridge, 1988.
12. W. Wundt. *Vorlesung über die Menschen- und Tierseele.* Voss Verlag, Leipzig, 1922.